Epitaxial Technologies for SiGeSn High Performance Optoelectronic Devices

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Description:
OBJECTIVE: Develop SiGeSn epitaxy on silicon and germanium substrates for new degrees of freedom in optoelectronic devices operating in the wavelength range between 2.0 and 5.0 micrometers. DESCRIPTION: Conventional mid-infrared materials based on the III-V (GaInSb) and the II-VI (HgCdTe) materials are relatively expensive and incompatible with silicon-based integrated circuit processing. SiGe technology is pervasive for electronic applications, but the indirect energy gap prevents extensive applications in optoelectronics. Recent progress on SiGeSn (Silicon Germanium Tin) source materials and the promise of a direct energy gap for certain compositions promises significant optical performance, similar to the III-V compounds, but with compatibility with silicon circuit processing. In order to verify the expected materials parameters, and to make further breakthroughs, innovations are needed in growth, device and structure fabrication. SiGeSn emitters and detectors must be grown and characterized to determine their attributes and limitations. One significant challenge involves the epitaxy of high quality layers on silicon and germanium substrates, depending on application. Compared to conventional SiGe epitaxy, the main limitation comes from the need to modify the growth conditions, such as reducing the substrate temperature. Novel CVD materials are required such as deuterated stannane as the Sn source. The optimum growth parameters are solicited to produce device-grade material. Once high quality epitaxy is available, it is important to find how device performance depends on material properties. With the compositional dependence of lattice constant and band gap, the optimum layer structures, and heterostructure and superlattice combinations are sought. Interesting devices based on strained layer superlattices and

quantum cascade mechanisms can be designed and fabricated. While SiGe and III-V optoelectronic devices have been well characterized in terms of band offsets, optical confinement, and radiative recombination, little is known about these effects in SiGeSn. Innovative ideas leading to effective SiGeSn optoelectronic devices are solicited. PHASE I: Demonstrate the feasibility to fabricate optoelectronic devices by the growth of epitaxial SiGeSn films on Si or Ge substrates either by MBE (Molecular Beam Epitaxy) or CVD (chemical vapor deposition) methods. Provide experimental evidence for a direct energy gap and significant optoelectronic performance, including high optical absorption and efficient infrared emission. PHASE II: Fabricate and characterize infrared emitters and detectors operating within the spectral range of 2 - 5 um. Demonstrate significant performance through enhanced and longer wave performance compared to other Group-IV detectors, and by efficient light emission comparable to that of Group-III-V materials. PHASE III DUAL USE APPLICATIONS: The device quality SiGeSn films will be used to make infrared device structures as required by military and commercial customers including those who manufacture integrated circuits and IR optical emitters and detectors.